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REUSE OF HOSPITAL WASTE AS DRIP EMITTERS FOR OKRO *(ABELMOSCHUS ESCULENTUS (L.) MOENCH)* PRODUCTION

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Abstract
Reusable waste plastic drip chamber of infusion sets were retrofitted and evaluated for drip irrigation applications. The drip chambers were carefully collected from local hospitals in Abeokuta, sorted and sterilized in hydrogen peroxide solution for 24 h and were evaluated for its systems characteristics and applicability for drip irrigation on the field using an extra early cultivar (NHAe47-4) of Okro (*Abelmoschus esculentus*) as a test crop. The study revealed that the emitter has a mean discharge, emission uniformity (E_u), Manufacturers' Coefficient of Variation (C_v), Christiansen's Uniformity Coefficient (CUC), Distribution Uniformity (DU) and Statistical Uniformity (SU) of 1.83 l h^{-1}, 88.12%, 0.06, 96.71%, 95.73% and 95.87% respectively at an operating pressure of 65.6 mbar, which implied that it performed creditably well in conformity to international drip irrigation standards. The system delivered the daily water requirement for okro in 14.3 min. Mean plant height, leaf area index and mean fresh fruit weight of okro at 76 days after sowing (DAS) was 1.12 m, 0.96 and 0.68 g per plant stand respectively. Crop yield of 15.1 tons ha^{-1} obtained indicates that the system performance is very satisfactory in comparison to okro yield in the region, while the low system cost of \$1.4/m^2 is very cheap for Sub-Saharan Africa. The system is recommended for use to maximize water use, enhance crop production and reduce hospital solid waste. However, for health reasons, only those drip chambers used to deliver dextrose in hospitals are recommended for reuse after sterilization.

Keywords: Hospital Waste, Reuse, Food Security, Irrigation, Crop yield.

1. Introduction

The food security challenge of Sub-Saharan Africa (SSA) has become a global discussion theme and has provided stimuli for the direction of food aid policies. The problem was exacerbated by the climate change phenomenon leading to drought and famine in many parts of the region. These changes will have serious impacts on the four dimensions of food security: food availability, food accessibility, food utilization and food system stability (Butt *et al.*, 2005). Irrigation technologies have been proven to assist in stabilizing food production in a number of countries by either supplementing or replacing the need for natural precipitation. It serves as crop insurance against drought and ensures continuous production in dry seasons. However, water availability is the major constraint to the full deployment of irrigation for crop production in this part of the world. The scarcity and or limited availability of irrigation water in SSA makes it necessary to develop efficient water conservation and management practices even in high rainfall areas (Sobowale *et al.,* 2015).

During the mid-1960 to mid-1980, Food and Agricultural Organization (FAO) estimated that the expansion of irrigation accounted for over 50% of the increase in global food production (Umali, 1993). Water conservation and management practices in irrigation invented modern irrigation techniques which aim at increasing the water use efficiency of production systems through the reduction in runoff and evaporation losses, reduced leaching of water and contaminants below the root zone and increased yields by providing optimum conditions for plant uptake of water and nutrients (Megersa and Abdulahi, 2015).

Assouline *et al.* (2002) opined that drip irrigation is an acknowledged technique for achieving high efficiencies in water use of crops by wetting only a limited part of the root zone with a much higher efficiency in terms of water conveyance, water application, water distribution and

uniformity when compared to other irrigation methods. Despite, the high efficiency of drip irrigation, the system still faces the challenge of adoption by peasant farmers, especially in developing countries due to its high cost, lack of knowledge about irrigation scheduling and farmer's misconception about the system (Sobowale *et al.,* 2015). In order to overcome the problem of huge system cost of drip irrigation technology, researchers in SSA have investigated a number of low cost – low technology materials that can replace expensive and or imported system components with promising results. These materials include the drip tubes (Mofoke *et al*., 2004), polyvinylchloride pipes (Edoga and Edoga, 2006), plastic drinking straw (Umara *et al.,* 2012), bamboo and drip tubes (Awe and Ogedengbe, 2011 and Ogedengbe, 2013) and medical needles (Sobowale *et al.,* 2015). The results from these investigations revealed that much improvement are still needed especially with system operating parameters which are still far from international drip standards and cost concerns. A vast majority of imported gravity drip kits are usually sold without the water tanks or plastic barrels, and this gives an incomplete system cost. The cheapest drip system developed in SSA is presently the one presented by Sobowale *et al.* (2015) at a rate of \$3 (USD)/m^2 and it includes a 205 liters barrel for water storage; which implies that a smallholder farmer will need about \$30,000 (USD) in drip irrigation system investment to cultivate one hectare farmland. This is however still unattainable for smallholder farmers considering the gross national income (GNI) per capita of the 46 SSA countries which was put at \$3,383 (UNDP, 2016). Further research is still needed to bring down system cost so that food production can be enhanced in the region. A veritable means of doing this will be to seek alternative materials which will be cheaper and easy to source.

The intravenous (I.V.) giving set is used in hospitals across the world to deliver injections (with a syringe at higher pressures) or infusions (typically using only the pressure supplied by gravity) directly into a vein. It is the fastest way to deliver medications and fluid replacement (such as correcting dehydration, correcting electrolyte imbalance, delivering medications, and for blood transfusions) throughout the body. The design concept of this study is that the drip chamber of the giving set could be retrofitted and reused especially the ones used to deliver infusions such as dextrose. The spent giving sets are usually incinerated in big hospitals along with other hospital wastes or buried in sanitary landfills. These sets are polyethylene in nature and are not biodegradable. Lee *et al.* (2002) elucidated the potential of recycling and reusing plastic medical wastes while Tsakona *et al*. (2007) opined that these wastes are high risk sources of infectious diseases. However, the polyethylene waste materials that are reusable can be sterilized using a variety of means as practiced in health care facilities (HFCs). Coker *et al.* (2009) quantified and characterized medical wastes generated in HCFs in Nigeria and found that ~3% was deemed infectious and highlighted the opportunities for composting, reuse and recycling.

Okro (*Abelmoschus esculentus* (L.) Moench*)* is the only vegetable crop of significance in the *Malvaceae* family and it is regarded as the oldest cultivated crop (Panigrahia and Sahub, 2013). The crop is cultivated for its green non-fibrous fruits or pods containing round seeds, harvested when immature and eaten as a vegetable. It is an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diets of the SSA countries (Iyagba *et al.,* 2013). The production of the crop in SSA is still at a subsistent scale by smallholder farmers and its availability is limited to the wet season when there is enough rain to aid its cultivation. The crop is usually expensive in the dry season as its cultivation is limited to valley bottoms where there is usually the availability of residual moisture. Furthermore, there has not been concerted effort to irrigate okro production in SSA which is probably the reason for the dearth of important irrigation design parameters for the crop in literature, even in FAO archives.
The objective of this study was to adapt and evaluate the use of the drip chamber of an I.V. hospital waste as a drip irrigation emitter and carry out field tests on same for the production of an extra early cultivar of Okro (NHAe47-4).

2. Materials and method

2.1 Materials

The drip irrigation system was constructed with the following materials: adapted emitters, 18.75 mm hose, 202 litres PVC drum, 20 litres bucket, 12.5 mm hose, 25 mm back nut, 18.75 – 12.5 mm adaptor, PVC gum, 18.75 mm valve, 18.75 mm end cap, 12.5 mm end cap and PVC connectors. Planting materials included; 72 pots, Okro seeds, NPK 15-15-15 fertilizer, Knapsack sprayer, Screen house etc.

2.2 Study site

The study was conducted at the Lowland Teaching and Research Farm of Federal University of Agriculture, Abeokuta, Nigeria on Lat. 7^o14^1N and Long 3^o26^1E and at an altitude of 128 m above mean sea level. The location chosen has a slope ranging between 1 – 3 %. The area has derived Savannah vegetation with mean annual temperature and annual rainfall of 27.1 °C and 1,238 mm respectively; the driest month in the year is December with 13 mm of rainfall while the wettest month is June with 197 mm. The land slope at the location was range between 2 – 3 %.

2.3 System layout, Component sizing and Irrigation design

The adapted emitter was the emitter chamber of a medical I.V. set shown in Figure 1. A 2mm wire stake was fitted to the emitter to ensure proper positioning at the base of the plants. The full system and set up in the screen house consisted of a 202 litres water barrel placed on a wooden stand of 0.70 m height which served as the main reservoir for water storage. This was connected to a 20 litres buffer bucket to achieve constant pressure head flow of 65.6 mbar in the system. The water flow from the bucket was filtered via a line filter and was controlled by an 18.75mm gate PVC valve before flowing into the mainline and subsequently into the three Laterals of 12.5 mm garden hose through a reducer tee (18.75mm – 12.5 mm). The plot size was 8 m x 5 m and it was able to accommodate 72 emitters at a rate of 24 emitters per lateral using the standard spacing for okro on the field (0.7 m inter row and 0.6 m intra row) according to Sakariyawo *et al* (2014). Because the system was tested using a potted experiment, the laterals were placed on bamboo stakes at a height of 30 cm (height of plastic pots). This arrangement was carefully designed so as not to distort the constant pressure head of 65.6 mbar (0.67 m of water) in the system. Figure 2 shows a 2D system layout and photos of the experimental set up. The emitter has an internal volume of 4.52 ml and an inlet diameter of 2 mm, the discharge end was retrofitted with an orifice of 1 mm diameter. Potted experimental setup of size 8m x 5m in a screen house was used to evaluate the system, the use of screen house helped to prevent insects and disease infestation. CropWat 8.0® software was used to design for the irrigation water requirement of Okro and irrigation scheduling using standard procedure. This was however not without challenges because very limited information on irrigation parameters of okro plant is available in literature. Pertinent parameters such as length of growth stages, Kc values, root zone depth, critical depletion and yield response factor were elicited from that of cotton which is a botanical cousin plant of okro from the same family (*Malvaceae*).

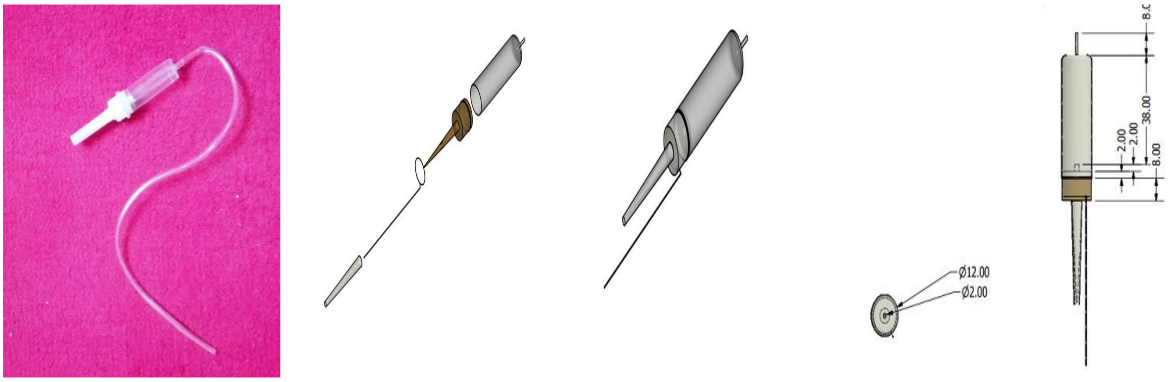

Figure 1: Adapted Emitter in diagram

Figure 2: 2D System layout and crop growth in screen house

2.4 Agronomic and field evaluation

The top soil (0 – 20 cm depth) used was obtained from the Teaching and Research Farm of Federal University of Agriculture, Abeokuta, Nigeria and was characterized for its physico – chemical properties. Soil particle size distribution was determined according to the protocol suggested by Bouyoucos (1962) while textural class of the soil was based on the USDA textural triangle. The soil pH was determined using soil: water ratio of 1:1 and using a pH meter (glass electrode) according to McLean (1982). The organic content of the soil was determined using wet oxidation method (Walkey – Black Method) as modified by Allison (1965). Total Nitrogen was determined using modified micro Kjeldahl digestion technique (Jackson, 1962). Other pertinent properties determined include Phosphorus, P, Potassium, K, Magnesium, Mg, and Calcium, Ca. The pots were filled with 8 kg of top soil and established in a screen house

according to the experimental layout shown in Figure 2. Initial irrigation was carried out to saturation in the pots to bring the soil to field capacity before the drip emitter irrigation schedule for the experiment commenced. A blanket application of NPK 15:15:15 inorganic fertilizer was carried out at the rate of 400kg ha^{-1} (equivalent to 1.43g per pot supplying 60kg N ha^{-1} as recommended N rate for okro). The cultivar of okro used to test the system was an extra early variety (NHAe47-4) of okro developed by Nigerian Institute for Horticulture Research and Training (NIHORT), Ibadan, Nigeria. It was sown on 17th November, 2016 at a rate of 3 seeds pot^{-1} and later thinned to one plant pot^{-1} two weeks after sowing (WAS). The experimental design was a Completely Randomized Design (CRD) with a single irrigation treatment of refill to 100 % field capacity in three replicates (Laterals) of 24 plant stands per replicate.

2.5 Data collection and analysis

The performance characteristics of the emitters were evaluated under gravity. Variations of emitter discharge along each lateral were determined by measuring individual discharge of each emitter to evaluate the need for pressure compensation. Pertinent system parameters in line with international drip standards such as Mean discharge, Standard Deviation, Manufacturer's coefficient of Variation, emission uniformity, distribution uniformity, Christiansen's uniformity coefficient, and statistical uniformity coefficient were also determined according to the methods described by Sobowale *et al.* (2015). The results were compared with American Society of Agricultural and Biological Engineers (ASABE) standard for drip irrigation (ASAE, 2003). Growth parameters of okro such as plant height was collected using a meter rule on ten randomly selected tagged plants per lateral to measure from the soil level in each pot to the tip of the plant once at 76 DAS (by last harvest); leaf area was determined manually once at onset of fruiting when maximum leaf area is attained according to equation 1, advanced by Sakariyawo *et al.* (2014); leaf area index was determined as a ratio of leaf area to spacing (Sakariyawo *et al.* 2014). Yield parameters like number of fruits per plant was collected by counting the number of fruits at each harvest time from each plant and the mean recorded; fresh fruit weight per plant was measured using a sensitive weighing balance with sensitivity of 1 mg and the mean recorded; and fresh fruit yield (tons ha^{-1}) was obtained by converting the mean fresh fruit weight per replicate (Laterals) to per hectare basis using the spacing of 0.75 m x 0.60 m as employed in the experiment giving a population of 22,222 plants ha^{-1}. Regression analysis was carried out to evaluate emitter discharge variation with length along lateral, analysis of variance (ANOVA) was also done to evaluate variations in emitter discharges using SAS 9.1.3®.

$$Y = 115x - 1050 \tag{1}$$

where: Y is the leaf areain cm^2 and x is the length of the leaf in cm.

3. Results and Discussion

3.1 Hydraulic Performance of Adapted Emitter

The discharge measurement obtained from each of the 72 emitters are presented in Table 1. At a constant pressure head of 65.6 mbar, the discharge obtained in all the emitters range between 1.7 – 2 L h^{-1}, with a mean value of 1.83 L h^{-1}. The standard deviation of emitter discharge of 0.075 indicates an improved uniformity of water discharge in the system, which is a very good improvement over that reported by Mofoke *et al*. (2004) and Sobowale *et al.* (2015). This shows that the emitter has suitability for a wide range of vegetable crops, the discharge can be increased by increasing the pressure head in the system but care must be taken when doing this, to prevent damage to shallow rooted crops. Table 2 shows the result of the analysis of variance of the measured discharges of the 72 emitters at 5% significant levels; the result $F_{calc.}(1.948) > F_{crit.}(1.766)$ indicates that there were significant differences in the emitter discharges observed within each of the laterals while the result that $F_{calc.}(0.409 < F_{crit.}(3.199)$ indicates that there were no significant differences among the observed emitter discharges between the three laterals of the

system. The above result was acceptable because the P-value of 0.027 < 0.05 indicates differences in discharges along the lateral. On the other hand, P-value of 0.666 > 0.05 also confirms that there were no significant differences in emitter discharges between the three laterals of the system. The implication of these is that the slope of the land is largely responsible for emitter discharge variation since such variation is only limited to the direction along the laterals.
The results from other performance characteristics of the drip system are presented in Table 3. The new emitter shows a good conformity to ASAE (2003) drip irrigation standard; the emission uniformity is the most important factor in drip irrigation system design. The adapted emitter belongs to the category of point source emitters with a low Manufacturer's Coefficient of Variation that can support efficient water application. The improved performance may be attributed to the creation of a constant pressure head (65.6 mbar) in the system using a buffer bucket after the main barrel. The candle filter used also prevented clogging within the system throughout the period of experimentation. The emitter was however found to become brittle after 2 years of use, and this was linked to the effect of ultraviolet rays of the sun, the solar effect may be reduced by manufacturing the emitter in black colour.

Figure 3 shows the variation of emitter discharge along each of the 3 laterals. According to ASAE EP405.1 (ASAE, 2003), the Manufacturer's Coefficient of Variation (C_v) of the adapted emitter of 0.06 is just a step below the best possible value of <0.05 indicating that the emitter performed creditably well under imposed conditions. There is however the possibility of achieving better results if the test were conducted on flat beds for growing vegetables. Emission Uniformity (EU), Distribution Uniformity (DU), Christianson's Uniformity Coefficient (CUC), Statistical Uniformity Coefficient (Us) of 88.12%, 95.73%, 96.71% and 95.87%, respectively, was within the acceptable limit of the ASABE standard for point source emitters. This result represents an improvement over the constant head emitter reported by Sobowale *et al.* (2015). The reuse of the I.V. sets from hospital waste greatly contributed to the reduction in system cost compared to other previous attempts. It is of grave importance that care must be taken during collection and sorting I.V sets, to ensure that only the sets used to deliver dextrose are reused after sterilization with hydrogen peroxide solution, this is because such sets are less harmful according to Coker *et al.* (2009). The sets used for blood transfusion should never be reused but disposed along with other hospital wastes because it is a high risk source of infection and it is against medical practice.

Table 1: Distribution of Emitter Discharge (L h^{-1})

Emitter Nos.	**Lateral 1**		**Lateral 2**		**Lateral 3**	
	A	B	A	B	A	B
1	1.8	1.8	1.7	1.8	1.7	1.8
2	1.8	1.8	1.8	1.7	1.8	1.7
3	1.8	1.8	1.9	1.8	1.8	1.8
4	1.8	1.9	1.8	1.8	1.7	1.8
5	1.7	1.8	1.7	1.9	1.8	1.8
6	1.8	1.9	1.9	1.7	1.9	1.8
7	1.8	1.9	1.9	1.8	1.9	1.9
8	1.8	1.8	1.8	1.9	1.8	1.8
9	1.7	1.8	1.8	1.9	1.9	2
10	1.8	2	1.8	1.8	1.9	1.8
11	1.8	1.9	1.9	1.8	1.9	1.9
12	1.9	1.8	1.9	2	2	1.9
Mean	1.77	1.83	1.81	1.81	1.81	1.82
St. Dev.	0.051	0.067	0.075	0.086	0.090	0.077

Table 2: Analysis of variance of emitter discharge

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Within Laterals	0.197	23	0.008	1.948	0.027	1.766
Between Laterals	0.003	2	0.001	0.409	0.666	3.199
Error	0.203	46	0.004			
Total	0.404	71				

Table 3: Performance Characteristics of the Adapted emitter

Parameter	Values	Remarks
Mean Discharge	1.83 L h^{-1}	Excellent for vegetable crops
Standard Deviation	0.075	Within Acceptable limits
Manufacturer's Coefficient of Variation (C_v)	0.06	ASAE EP405.1 rating- Average but could be improved
Emission Uniformity (EU)	88.12%	Within Acceptable limits
Distribution Uniformity (DU)	95.73%	Within Acceptable limits
Christianson's Uniformity Coefficient, (CUC)	96.71%	Within Acceptable values
Statistical Uniformity Coefficient, (Us)	95.87%	Within Acceptable limits
Operating Pressure	65.72 mbar	
Irrigation Time (Okro Plant)	~15 mins.	Time effective system
Unit cost (40 m^2)	₦16, 778 ($55)	Very low cost

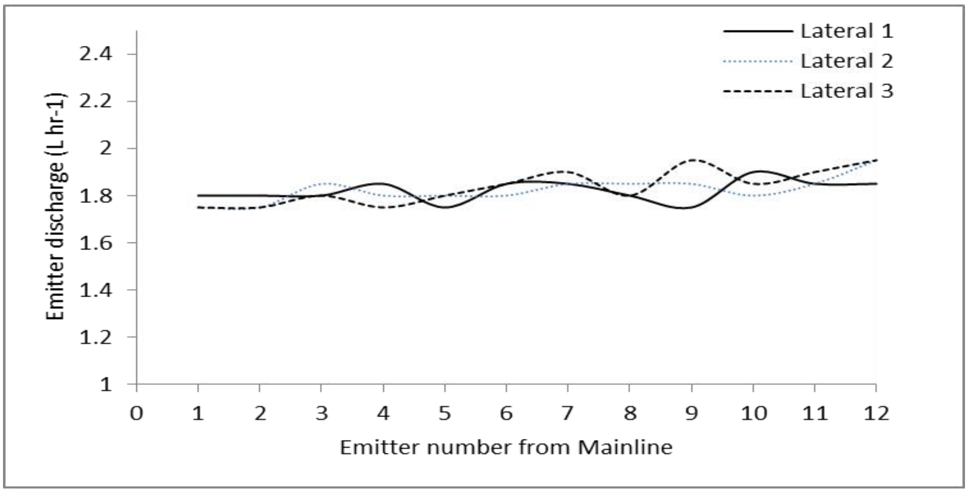

Figure 3: Emitter discharge variations along irrigation laterals

3.2 Irrigation scheduling design

The use of CropWat 8.0® software to design for the crop water requirement of okro posed a great challenge because limited information on important parameters for irrigation design for okro are available in literature. Cotton, as a cousin crop with okro was used to elicit these parameters. The implication of this is that more research needs to be carried out on the okro crop. The Food and Agricultural Organization's archives are also scanty on information concerning the crop. Table 4 shows the combinations of parameters for irrigation scheduling needs of okro on the CropWat platform. The CropWat software revealed that the actual crop evapotranspiration for okro ranged between 2.1 – 2.7 mmday^{-1} within the 76 days of the four growth stages (initial, development,

mid-season and late season); the gross irrigation demand ranged between 9 – 11.3 mm, while water application volume for the crop ranged from 0.374 – 0.469 L within the four growth stages. The mean irrigation time required to deliver this requirement using the adapted emitter was 14.3 min. This was found to be a remarkable improvement over the existing drip emitters developed in the region. Irrigation time however differed from crop to crop. The system was found to be time effective; hence its deployment in SSA will boost agricultural productivity in the dry season. The use of hospital waste as a system component (emitter) makes it affordable to smallholder farmers and reduces the waste load of HCFs.

3.3 Soil characteristics, growth and yield parameters of okro

Results of the physico – chemical characteristics of the top soil used in the experiment are presented in Table 5, the soil was moderately acidic with a loamy sand texture which will support the cultivation of vegetable crops. Essential soil nutrients were found to be slightly adequate; however, the Nitrogen and Potassium levels need to be boosted through fertilizer application. A blanket application of NPK 15:15:15 inorganic fertilizer was carried out at the rate of 400kg ha^{-1} (equivalent to 1.43g per pot supplying 60kg N ha^{-1} as recommended N rate for okro). Crop emergence occurred 2 days after sowing (DAS) while about 90% of the entire plants emerged at 3 DAS. From observations, the okro plants commenced fruiting at 43 DAS against the normal 47 DAS.

This confirms the cultivar (NHAe47-4) as an early maturing variety of okro. Table 6 shows the observed mean leaf area, leaf area index and plant height for each plant in each replicates (lateral). The observed moderately high results of mean leaf area, leaf area index and plant height corroborates the work of Sakariyawo *et al.* (2014) who reported similar results on the growth and yield parameters of okro with good agronomic management practices in South west, Nigeria. The mean numbers of fresh fruit per plant and mean fresh fruit weight of okro per plant per harvest at 55, 62, 69 and 76 DAS are presented in Table 7. The mean fresh fruit weight per replicate of 16.23 g was found to be equivalent to 0.68 g per plant stand; multiplying this value by the number of plant stand that could possibly be planted on an hectare of land (22,222 stands – spacing of 0.75 m x 0.6 m) yielded a total of 15.1 tons ha^{-1}.

Aderibigbe and Hussaini (1998) reported significant influence of irrigation water scheduling and applied mineral nutrients on growth and yield parameters of tomato (*Lycopersicon esculentum,* Mill.) sown in pots in the dry season in Northern Guinea savannah of Nigeria. Considering the significant and reasonably high okro fresh fruit yield of 15.1 t/ha in the screen house in the dry season, this could be attributed to the moderate and direct application of irrigation water to the root zone of the test crop achieved by the adapted drip emitters in this experiment. The performance of the drip system is very satisfactory, the system is easy to set up and can be understood by uneducated farmers; the land coverage could also be enhanced by increasing the system operating pressure by raising the water tank. This gravity system can be used in the remotest farmland and for smallholder production of high value vegetable crops; it is however important to test the system with other important crops.

Table 4: Irrigation Design fundamentals for Okro using CropWat 8.0®

Country: Nigeria	Station: FUNAAB
Altitude: 128 m	Latitude: 7.17 °N Longitude: 3.43 °E

Monthly Eto (Penman-Monteith)

Month	Min Temp	Max Temp	Humidity	Wind	Sunshine	Rad	Eto
	°C	°C	%	(Km/day)	(hrs)	$MJ/m^2/day$	(mm/day)
January	20.6	35.4	69	61	4.0	14.0	3.32
February	22.2	37.2	73	74	4.1	15.0	3.72
March	23.1	36.5	78	83	3.9	15.4	3.83
April	22.6	35.8	79	76	4.1	15.8	3.84
May	21.9	33.7	83	68	4.6	16.1	3.66
June	21.3	32.6	83	61	3.4	14.0	3.17
July	21.1	31.2	87	67	2.5	12.7	2.85
August	20.8	31.3	88	67	2.3	12.8	2.83
September	20.7	32.2	86	60	3.1	14.1	3.09
October	21.2	33.1	84	53	3.7	14.5	3.16
November	22.8	34.8	79	51	4.7	15.2	3.40
December	21.1	35.1	74	53	5.0	15.1	3.41
Average	21.6	34.1	80	65	3.8	14.5	3.36

Dry Crop Data

Stage	Initial	Dev.	Mid.	Late	Total
Length (days)	13	22	27	24	86
Kc Values	0.68	-	0.79	0.54	
Rooting depth (m)	0.45	-	0.61	0.61	
Critical dep.	0.60	-	0.6	0.90	
Yield Res. Factor	0.20	0.50	0.48	0.25	0.85
Crop height (m)					

Irrigation Scheduling

Date	Day	Stage	Eta (mm/day)	Gross Irrigation (mm)	Application Volume (L)	Operation Time (mins)
17 Nov - 29 Nov	1 – 13	Initial	2.3	9.9	0.411	13.41
30-Nov	14	Dev	2.3	9.9	0.411	13.41
01 Dec - 10 Dec	15 – 24	Dev	2.4	10.1	0.42	14.09
11 Dec - 20 Dec	25 – 34	Dev	2.6	11.2	0.465	15.17
21-Dec	35	Dev	2.7	11.3	0.469	15.44
22 Dec - 31 Dec	36 – 45	Mid	2.7	11.3	0.469	15.44
1 Jan - 18 Jan	46 – 63	Mid	2.6	11.1	0.461	15.03
18 Jan - 20 Jan	64 – 65	End	2.6	11.1	0.461	15.03
21 Jan - 31 Jan	66 – 76	End	2.4	10.3	0.428	13.95
01 Feb - 10 Feb	77 – 86	End	2.1	9	0.374	12.19

Table 5: Physico – chemical characteristics of the top soil

Parameters	Value
pH (H_2O)	6.84
Organic Carbon (g kg^{-1})	1.64
Total Nitrogen, N (g kg^{-1})	0.53
Phosphorus, P (mg kg^{-1})	5.33
Exch. K (cmol kg^{-1})	0.11
Exch. Mg (cmol kg^{-1})	1.05
Exch. Ca (cmol kg^{-1})	2.63
Sand (%)	79
Silt (%)	6
Clay (%)	15
Textural Class (0 – 20 cm)	Loamy sand

Table 6: Growth parameters of NHAe47-4 cultivar of Okro

Replicates (Lateral)	Leaf Area (cm^2)	Leaf Area Index	Plant Height
1	267.1	1.08	1.17
2	253.5	0.92	1.06
3	284.6	0.96	1.13

Table 7: Yield parameters of NHAe47-4 cultivar of Okro

Replicate (Lateral)	Number of fresh fruit per plant					Mean fresh fruit weight (g) per plant				
	Days After Sowing (DAS)				Total	Days After Sowing (DAS)				Total
	55	62	69	76		55	62	69	76	
1	3	3	4	1	11	4.6	4.7	3	1.7	14
2	3	3	4	3	13	4.9	4.3	4.2	3.1	16.5
3	4	3	5	3	15	6	4.9	4.1	3.2	18.2
mean					13					16.23

4. Conclusion

A new drip irrigation emitter was adapted from the drip chamber of waste medical infusion set; the materials used in developing the gravity drip system were sourced locally and sterilized before being employed. The drip system was tested for pertinent performance characteristics and was found to conform to international drip irrigation standards; field evaluation using an extra early cultivar of Okro (NHAe47-4) indicated that the system is very applicable to high value vegetable crop production. The crop yield of 15.1 tons ha^{-1} obtained was comparable to similar results for conventional rain fed system of production and the system cost was found to be very cheap among the previous attempts of developing drip irrigation system in SSA. The utilization of reusable plastic wastes from HFCs in this study has opened a new horizon for waste reduction in hospitals and can lead to increased agricultural production in the dry season, thereby contributing to food security in the region. The risk of infection is very low when only infusion sets used to deliver dextrose is used after sterilization.

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